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The effect of earthworms and their activity on the amount of algae in the soil

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With 3 figures

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1. Introduction

Many authors (Zraževski 1957; Satchell 1958; Ghilarov 1963, 1965; Ština 1967; Brauns 1968) stress the significance of soil organisms including algae and earthworms. For the understanding of biological activity of soil it is important first of all to study mutual relations between different soil organisms (Törne 1963, 1964; Ghilarov 1965, 1968).

A number of authors (Gollerbach and Ština 1969; Pocienė 1963; Maksimova 1966) have investigated mutual relations between soil algae and bacteria, algae and higher plants. The positive effect of earthworms on the densities of microorganisms and plant harvests has also been established (Day 1950; Kazlovskaja 1969; Zraževski 1957; Jung 1967; Atlavinytė, Bagdonavičienė, Budavičienė 1968; Atlavinytė, Lugauskas 1972, etc.). Interesting studies were performed regarding the numbers of water algae and Protozoa on insects that may disseminate them (Revill, Stewart, Schlichting 1967).

We have found no information on the mutual numerical ratio between algae and earthworms in the soil.

While carrying out ecological investigations on algae and earthworms in the soil and elucidating the effect of earthworm densities on the numbers of microorganisms and on the intensity of humification of organic matter the first studies were performed that analyzed the influence of earthworms on the amount of algae (Pocienė, Atlavinytė, Grigaitė 1971). It is now necessary to establish the effect of earthworm densities on the amount of soil algae.

2. Methods

Vegetative and field experiments were carried out in 1969—1971. For the former experiments plastic 5 *l* pots were filled with 3—4 kg of sieved soil and different numbers (8; 16; 24; 32 or 10; 20; 30) of earthworms (*Allolobophora caliginosa* Sav. f. *typica*) were added. Vegetative pots containing 8 earthworms equalled 230 specimens per sq. m of soil under field conditions; it is such number of earthworms that is found on an average in Lithuanian soil during vegetation period; 16 earthworms in a pot equalled 460 specimens in a m^2, i. e. seasonal maximum and 32 earthworms was equal to 720 specimens of them in a m^2, i. e. very rare seasonal maximum (Visockis, Gedvilaitė, Atlavinytė 1962; Atlavinytė 1973). Experiments were performed in a soddy podzolic loamy sand (Vr, V), soddy podzolic sandy loam (Sd) and soddy gleyish sandy loam (K).

In vegetative pots the following experiments were made:

(1) algae were investigated when soil was fertilized by rye straw 60 g per pot (i. e. 17 tons per ha) for the first time in spring and the second time the following spring; in autumn when some variants were fertilized 30 g of naphthalene was scattered in the straw layer; in summer vegetative pots were kept in the open air, in winter they were taken into a hothouse (12—18 °C);

(2) algae were investigated without the plant cover (when barley was harvested) and with plants, in a non-fertilized and fertilized by urea (0.5 g of Nu, i. e. 196 kg per ha) soil.

Variants of field experiments were 1 m², isolated by polyethelene film up to 50 cm in depth. Earthworms were picked up by digging up soil layers in control variants; in other variants of the same size earthworm numbers were increased up to 500 specimens per m². We investigated algae when barley was harvested; such was the case with variants of non-fertilized and fertilized by straw soil.

All experiments had 3 replications. For the analysis of algae under field conditions soil was taken 0—1 cm deep and from vegetative pots soil was sampled mixing all the layers. The cells of algae were counted with the accuracy of a unit according to Ština (1956).

The observation of algae in the intestine of earthworms was performed after earthworms were held previously on the culture of algae artificially in laboratory and in soil under field conditions.

3. Results

3.1. The effect of earthworm densities on the numbers of algae in the soil fertilized by straw (vegetative pots)

It is known that for the numbers of algae, soil properties and organic fertilizers are of importance (Ština 1959). While elucidating the effect of earthworm numbers on the densities of algae we tried to perform our experiments in various and differently fertilized soils.

In the soddy gleyish sandy loam soil (K) fertilized by straw, algae were counted for the first and the second time after 4 months. Algae were found to be more numerous after the first than the second fertilization. In the variants with earthworms the amount of algae gradually decreased in both cases when the numbers of earthworms increased in vegetative pots, e. g. following the first fertilization algae decreased from 11.0 to 0.4 and the second time from 5.8 to 1.1 (in thousand/1 g of soil). All groups of algae decreased evenly and as blue-green algae and diatoms were less they completely disappeared when the numbers of earthworms were higher, i. e. 24 and 32 (see table 1).

In autumn when soils were fertilized with straw (K and soddy podzolic sandy loam — Sd) and after 5 months they were also analysed it was found that control variants of both soils had almost equal numbers of algae. The variants with 30 earthworms had no algae altogether. Variants that had as a fertilizer 30 g of naphthalene in a straw layer contained no algae either in control pots or in the pots with earthworms (table 2). It is to be mentioned that the number of earthworms and their activities in the soil accelerate straw humification from 10 to 50 per cent (Atlavinytė 1971).

To establish whether algae are decreasing equally intensively in the surface and deep layers according to the numbers of earthworms we analyzed soil K (fertilized with straw) of the vegetative pots, namely surface layer (0—1 cm deep) and mixed layers. When the densities of algae in different layers were compared, it became evident that only slightly higher densities of algae were found in a surface layer. In the variants with earthworms algae decreased evenly in both soil layers when the numbers of earthworms gradually increased (table 3).

Our data show that algae and earthworms propagate in vegetative pots in an equal manner throughout all the layers of the soil. In the arable layer of cultured soils algae also propagate evenly (Pocienė 1960, 1961).

Table 1 The effect of earthworms on the amount of algae in soil K fertilized by straw (Beginning of experiment 30. IX. 1969)

Time of algae fixation	8. IX. 1969							15. VIII. 1970						
Series of experiments	fertilized by straw for the first time (30. IV. 1969)							fertilized by straw for the second time (30. IV. 1970)						
algae (number of cells, thousands/1 g of soil)														
Variants	green		blue-green		diatoms		*Total*	green		blue-green		diatoms		Total
	1	2	1	2	1	2		1	2	1	2	1	2	
Control	8.2	4.4—13.9	1.8	1.4—2.5	1,0	0.7—1.1	*11.0*	0.0	0.0—0.1	5.3	1.3—11.9	0.5	0.1—0.9	*5.8*
8 earthworms	5.7	2.9—11.3	1.2	1.1—1.3	0.7	0.4—1.1	*7.6*	1.2	0.8—1.5	1.9	1.0—2.6	1.0	0.9—1.2	*4.1*
16 earthworms	3.7	1.4—6.9	0.8	0.7—1.1	0.2	0.0—0.7	*4.7*	0.6	0.3—0.9	1.1	0.1—2.6	0.7	0.4—1.1	*2.4*
24 earthworms	2.8	1.3—5.8	0.3	0.3—0.4	—	—	*3.1*	0.2	0.2—0.4	0.8	0.3—1.3	0.6	0.4—1.1	*1.6*
32 earthworms	0.4	0.4—0.5	—	—	—	—	*0.4*	0.4	0.3—0.9	0.1	0.0—0.4	0.6	0.2—0.9	*1.1*

1 — average; 2 — minimum-maximum. The same in Table 2, 4—6.

Table 2 The effect of earthworm densities on the amount of algae in the soil fertilized by straw with and by naphthalene (Beginning of the experiment 5. X. 1970. Time of algae fixation 15. III. 1971)

Series of experiments	fertilized by straw							fertilized by straw with naphthalene
Soil and variants	algae (number of cells, thousands/1 g of soil)							
	green		blue-green		diatoms		Total	Total
	1	2	1	2	1	2		
Soil-K								
Control	1.6	1.4—1.8	1.1	1.1—1.2	0.6	0.6—0.7	*3,3*	—
30 earthworms	—	—	—	—	—	—	—	—
Soil-Sd								
Control	1.2	0.9—1.3	0.3	0.3—0.4	2.6	2.4—3.0	*4.1*	—
30 earthworms	—	—	—	—	—	—	—	—

Table 3 The effect of earthworm densities on the amount of algae on the surface of the K soil (I), in its mixed layer (II) fertilized by straw (Beginning of the experiment 30. IV. 1969. Time of algae fixation 8. IX. 1969)

Variants	algae (number of cells, thousands/1 g of soil)							
	green		blue-green		diatoms		*Total*	
	I	II	I	II	I	II	I	II
Control	9.6	8.2	2.0	1.8	0.9	1.0	*12.5*	*11.0*
8 earthworms	6.9	5.7	1.4	1.2	0.6	0.7	*8.9*	*7.6*
16 earthworms	4.0	3.7	0.8	0.8	0.1	0.2	*4.9*	*4.7*
14 earthworms	2.9	2.8	0.5	0.3	0.1	0.0	*3.5*	*3.1*
32 earthworms	0.7	0.4	0.0	0.0	0.0	0.0	*0.7*	*0.4*

3.2. The effect of earthworm densities on the amount of algae in soils under plants and without them

In soils without plants, i. e. in soddy podzolic loamy sand — V and soil K, algae were investigated in 16 months, during the second season of vegetation. In both soils the densities of green and diatom algae were equal and blue-green algae were absent. In the variants with earthworms algae decreased gradually with the increase of earthworms (table 4).

Algae in soils under plants were checked after 4 months when barley was harvested (the soils were the same — V and K). In this case the amount of algae was not the same. Blue-green algae were more numerous in soil V, diatoms were absent in soil K. With the increase in the numbers of earthworms, algae gradually decreased in the variants with earthworms as in the above-mentioned cases. Comparing the same soils under plants and without them, algae were more numerous in soils under plants (17.0—10.7 and 9.9—3.4 against 2.0—0.5 thousands per 1 g of soil; table 4). It is so because in soils without plants earthworms exerted their biotical activities for a longer period and they have passed more soil though their digestive organs and therefore the amounts of algae remained there much more reduced.

Algae were also investigated in a soil under plants that was both fertilized with urea (Nu) and not fertilized by it (soddy podzolic loamy sand — Vr). In both cases the amounts of algae were almost equal, the difference being that in the fertilized soil algae were reduced more intensively in the variants with earthworms, e. g. in the non-fertilized variant from 13.0 to 5.0, in the fertilized one it was from 14.3 to 0.7 (thousand/1 g of soil). In

Table 4 The effect of earthworm densities on the amount of algae in the soil without plants and in the soil with plants (Beginning of the experiment 30. IV. 1969)

Time of algae fixation	15. VIII. 1970							8. IX. 1969						
Series of experiments	without plants							with plants (barley)						
Soil and variants	algae (number of cells, thousands/1 g of soil)													
	green		blue-green		diatoms		*Total*	green		blue-green		diatoms		*Total*
	1	2	1	2	1	2		1	2	1	2	1	2	
Soil-V														
Control	0.9	0.7—1.1	—	—	1.1	0.7—1.5	*2.0*	7.3	4.0—10.6	8.1	2.0—14.3	1.6	1.1—2.2	*17.0*
8 earthworms	0.6	0.4—0.7	—	—	0.8	0.2—1.3	*1.4*	n	n	n	n	0.9	0.7—1.1	
16 earthworms	0.9	0.4—1.4	—	—	0.3	0.2—0.4	*1.2*	n	n	n	n	n	n	n
24 earthworms	0.6	0.2—0.9	—	—	0.2	0.1—0.2	*0.8*	6.6	5.5—7.7	5.5	2.2—8.8	0.7	0.7—0.7	*12.8*
32 earthworms	—	—	—	—	—	—	—	9.7	6.9—12.5	0.6	0.0—1.1	0.4	0.2—0.7	*10.7*
Soil-K														
Control	1.0	0.8—1.3	—	—	1.0	0.9—1.1	*2,0*	8.8	6.3—10.3	1.1	1.0—1.2	—	—	*9.9*
8 earthworms	0.8	0.7—1.0	—	—	0.6	0.4—0.7	**1.4**	6.2	6.5—6.6	1.1	1.0—1.2	—	—	*7.3*
16 earthworms	0.5	0.2—1.0	—	—	0.3	0.2—0.3	**0.8**	5.0	3.2—6.9	0.9	0.8—1.1	—	—	*5.9*
24 earthworms	0.3	0.2—0.4	—	—	0.3	0.2—0.3	**0.6**	4.4	3.2—6.0	0.6	0.6—0.7	—	—	*5.0*
32 earthworms	0.3	0.2—0.4	—	—	0.2	0.1—0.2	**0.5**	3.4	1.7—5.5	—	—	—	—	*3.4*

n — not investigated.

Table 5 The effect of earthworm densities on the amount of algae in the fertilized and non-fertilized soil (after barley was harvested). (Soil: soddy podzolic loamy sand — Vr. Beginning of the experiment 30. IV. 1971. Time of algae fixation 15. VIII. 1971)

Series of experiments	non-fertilized algae (number of cells, thousands/1 g of soil)							fertilized — Nu						
Variants	green		blue-green		diatoms		*Total*	green		blue-green		diatoms		*Total*
	1	2	1	2	1	2		1	2	1	2	1	2	
Control	5.4	3.7—7.7	5.2	1.5—8.1	2.4	1.8—3.7	*13.0*	5.0	4.7—5.4	7.8	6.2—9.5	1.5	1.4—1.7	*14.3*
10 earthworms	3.0	1.5—4.5	4.4	1.4—6.6	1.9	1.1—3.3	*9.3*	3.3	2.2—4.4	2.4	2.2—2.6	1.4	1.4—1.7	*7.1*
20 earthworms	2.2	1.1—3.3	3.0	2.2—4.4	1.7	1.1—2.6	*6.9*	1.4	1.1—2.2	2.4	2.2—2.6	1.1	1.1—1.1	*4.9*
30 earthworms	1.1	0.0—2.9	2.8	2.2—3.3	1.1	0.7—1.4	*5.0*	0.4	0.0—0.7	0.3	0.0—0.7	—	—	*0.7*

Table 6 The effect of earthworms on the amount of algae in the field experiment (after barley was harvested). (Soil: soddy podzolic loamy sand — Vr. Beginning of the experiment 30. IV. 1970. Time of algae fixation 15. VIII. 1971)

Series of experiments	non-fertilized algae (number of cells, thousands/1 g of soil)							fertilized by straw (5. X. 1970)						
	green		blue-green		diatoms		*Total*	green		blue-green		diatoms		*Total*
Variants*)	1	2	1	2	1	2		1	2	1	2	1	2	
Control	3.2	2.5—4.4	0.6	0.6—0.6	1.2	1.1—1.5	*5.0*	3.1	1.8—4.7	3.4	1.8—5.8	0.7	0.6—0.8	*7.2*
500 specimens/m²	2.2	1.5—2.8	0.2	0.0—0.4	0.7	0.3—1.0	*3.1*	1.4	1.1—1.8	0.8	0.3—1.1	0.7	0.4—1.1	*2.9*

*) the size of a variant is 1 m².

the variant fertilized with urea the total amount of algae was reduced up to 20 times while diatoms in the variants with 30 earthworms have disappeared altogether (table 5).

3.3. The effect of earthworm numbers on the amount of algae in soil — Vr (non-fertilized and fertilized by straw) under plants in field experiments

In field experiments (when barley was harvested) blue-green algae were more numerous in straw-fertilized variants (3.4) than in the non-fertilized ones (0.6) thousand/1 g of soil). In this case the amounts of other algae remained almost equal. In the variants with earthworms (500 specimens/m²) in non-fertilized and straw-fertilized soils the amount of algae was almost two times less when compared with control figures.

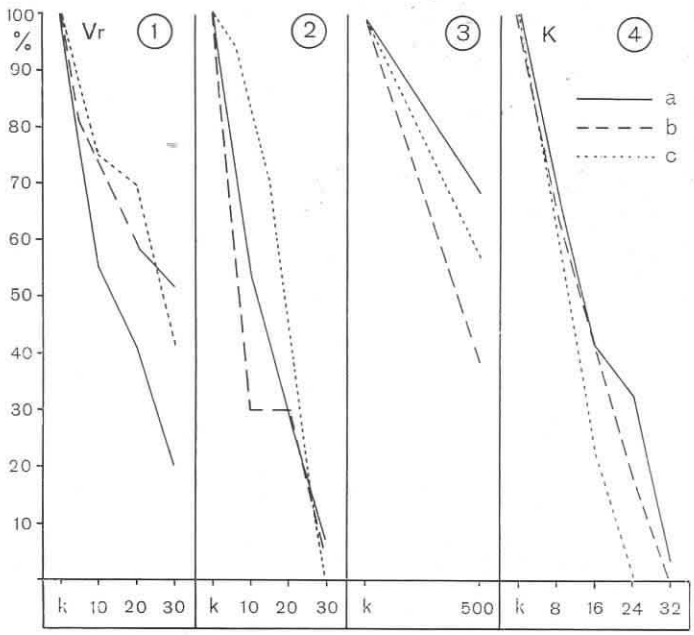

Fig. 1. Gradual decrease of algae in relation to the densities of earthworms (%): Vr, K — type of soil; 1 — non-fertilized; 2 — fertilized with Nu; 3 — non-fertilized (in a field experiment barley grown everywhere; 4 — fertilized by straw (without plants); the numbers of earthworms in a vegetative pot being 8; 10; 30, in a field experiment 500 specimens per m²; a — green algae b — blue-green algae; c — diatoms; k — control.

These data indicat that a reverse ratio is existing between the numbers of earthworms and those of algae both in vegetative pots and under field conditions (table 6, fig. 1).

It is to be noted that the effect of different numbers of earthworms is also positive on the oat crops both in the vegetative pots and in field experiments. Oat crops increase by 50—200 per cent.

3.4. Algae investigations in the intestine of earthworms

Having observed gradual decrease of algae when the numbers of earthworms increased we undertook some studies to elucidate the causes of this phenomenon. For this purpose we observed algae in the intestine of earthworms in the laboratory.

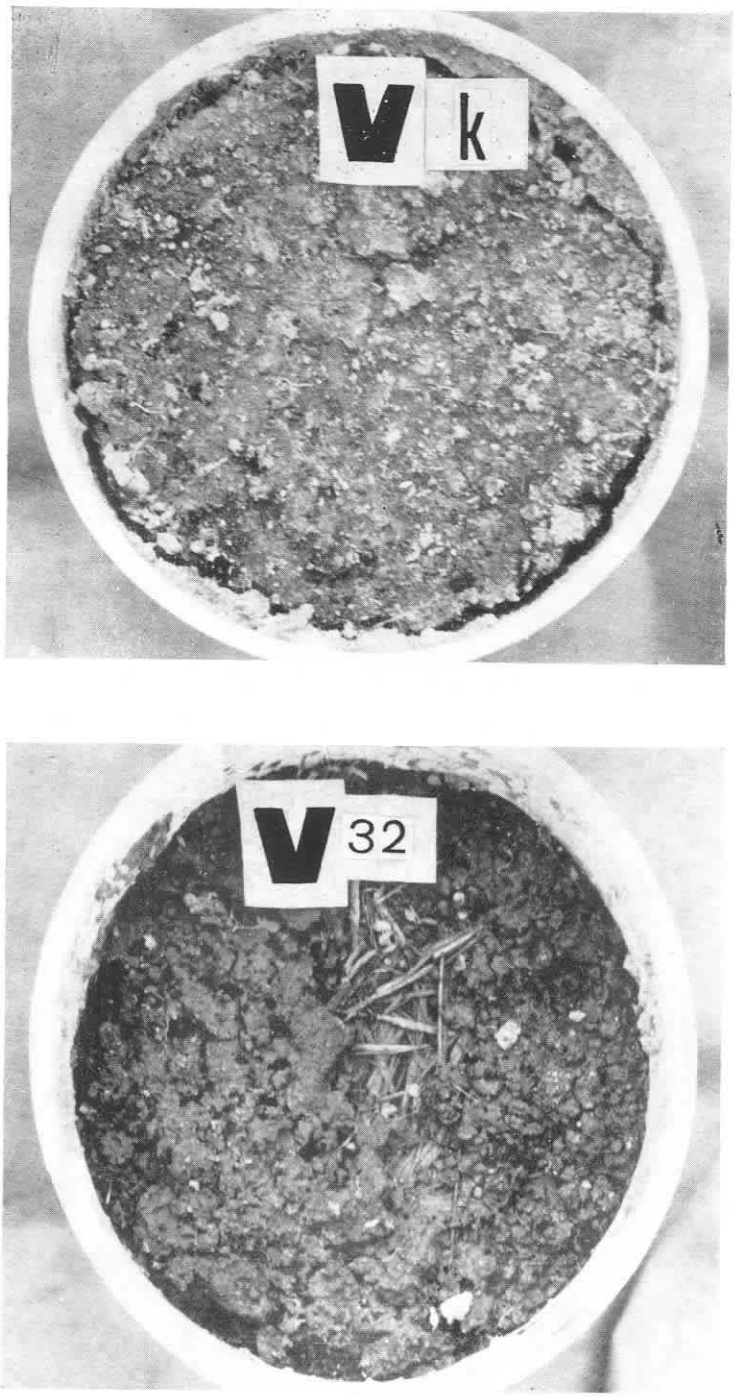

Fig. 2. The effect of earthworms on the structure of the V soil (on the surface of a vegetative pot): k — control; the number of earthworms in a pot being 32.

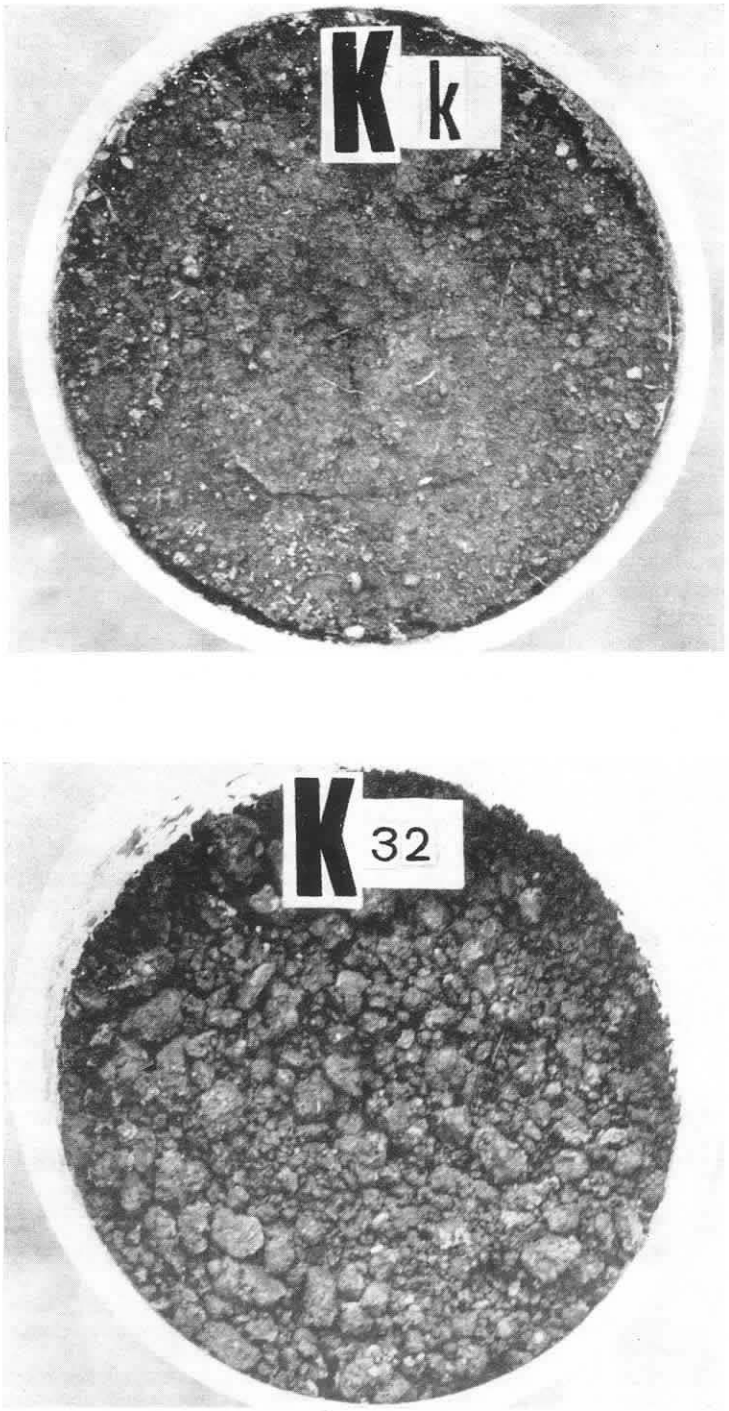

Fig. 3. The effect of earthworms on the structure of the K soil; for other explanations see fig. 2.

Earthworms (*A. caliginoas*) were taken from the soil, put in the wet chamber on the filter paper and kept there for 3 days in order that all the soil be removed from their intestine. The earthworms having no soil in them were put in Petri dishes (5 dishes each containing 2 earthworms). On agarized medium mixed algae cultures were grown in Petri dishes. Petri dishes that contained earthworms were analyzed with luminescent microscope and no destruction of algae cells was noticed there. This showed that mucous substance and excrements of earthworms were not toxic for algae.

Intestine contents of earthworms kept in Petri dishes were looked through by microscope in separate parts. In the front part of intestine following species of green algae were found: *Asterogloea* sp., *Schisochlamis* sp., *Chlamydomonas* sp.; blue-green algae found were *Calothrix jelenkinii* (a dominating species), *Stratonostoc microscopicum*, *Amorphonostoc punctiforme*, *Cylindrospermum* sp., *Phormidium* sp. and others; diatom species were *Pinnularia* sp., *Navicula* sp. In the middle part of the intestine bacteria prevailed though algae cells were also seen there. The back part of the intestine contained only bacteria. Various amounts of bacteria in different parts of the earthworm intestine have been observed by Day (1950) and Kazlovskaja (1969). We also looked through the microscope at the intestinal contents of earthworms kept in the soil. In the soil that has previously been in the intestine we could recognize only some cells of green algae while only cell walls were seen of those algae that belonged to other groups.

These two observations have shown that algae ingested with the soil were digested. This fact accounts for the disappearance of algae when there is a larger amount of earthworms in the soil.

Vokhmyanina (1972) reports that she succeeded in growing algae (*Chlorella* sp.) obtained from the digestive tract mites (*Tyrophagus*) and excrements of Enchytraeidae. This shows that not all algae are digested in the digestive tract of minute animals.

Regular decreases in algae densities in relation to the numbers of earthworms in all the above experiments is a direct consequence of earthworm activity and their ability to process large volumes of soil. A very distinctive difference was noted in the soil structure in vegetative pots when the controls were compared with those containing earthworms (fig. 2—3). The disappearance of some algae in the variants with earthworms shows that earthworms have passed all the soil of a vegetative pot through their digestive tract. In nature earthworms also pass through their digestive tract large amounts of soil (5.6—210 t/ha) Dunger 1964).

Thus the results of present investigations have shown that in calculating the amount of algae and their biomass it is not enough to take into account ecological and agrotechnical factors; of great importance is also the densities of earthworms situated in the soil.

4. Conclusions

There is a close correlation between the amount of algae and the densities of earthworms in the soil. When the densities of earthworms increase, the amount of algae decreases.

The effect of earthworms on separate groups of algae — greens, blue-greens and diatoms — is the same. As blue-green algae and diatoms are less numerous, they consequently disappear sooner than green algae when the densities of earthworms are greater. The passage of soil through the digestive tract of earthworms results in the digestion of algae.

5. Резюме

(О. Атлавините и Ч. Поцене: Количество водорослей в зависимости от деятельности и численности дождевых червей в почве)

На основе проведенных в 1969—1971 гг. исследований в вегетационных сосудах и полевых опытах доказывается большая зависимость между количеством водорослей и численностью дождевых червей в почве, с увеличением количества червей численность водорослей пропорционально уменьшается.

Влияние червей на отдельные группы водорослей одинаковое. Сине-зеленых и диатомовых водорослей бывает меньше, поэтому при большем количестве червей они быстрее исчезают. Черви, пропуская почву через пищеварительные органы, имеющиеся в ней водоросли переваривают.

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